

# **Method for Imaging a Continuously Moving Object**

## **Field of Invention**

The invention relates to imaging, and more particularly to the elimination of motion blur when projecting stationary images on a moving object.

## **Background on the Invention**

In various industries employing photo-lithography there is a desire to use two-dimensional light valves to project an image on a moving object. The typical use is projecting a UV image in order to expose a UV sensitive material such as photoresist or photopolymer. The advantage of two-dimensional light valves over a laser is that low brightness sources, such as arc lamps, can be used. The best known device using a light valve to project an image is the video projector, used to project video and computer generated images on a screen. It is an object of this invention to utilize a low cost and readily available video projector as means of projecting images on moving objects. Prior art systems for projecting on moving objects use one of the following methods:

- a) A step-and-repeat motion of the object, thus object is stationary at the moment of imaging;
- b) Synchronizing the image to the motion by shifting the data in the light valve  
(For example, U.S. Patents 5,049,901; 5,208,818; and 5,132,723)

- c) Moving both the light valve and the object at the same time (For example U.S. Patents 5,870,176 and 6,060,224);
- d) Dividing the image into columns and using an acousto-optic modulator to synchronize the image with the motion one column at a time. (For example, see U.S. Patents RE37,376E and 5,923,359).

None of the above inventions allow the use of a stationary light valve based projector which projects a series of stationary images in a rapid sequence to image a continuously moving object. The importance of this mode is that it allows the use of a low cost, off-the-shelf video projector as a lithographic imaging device, without requiring step-and-repeat type motion of the object or the imaging source. The main advantages of a continuous mechanical motion over a stepped motion is in a smoother, more accurate and more reliable mechanical system.

The present invention is particularly useful in the following applications: the production of printing plates (both lithographic and flexographic), the production of printed circuit boards (also known as “direct imaging”), the production of displays and the production of solid objects from photopolymer.

### **Summary of the Invention**

The invention uses a scanning device between the image source, typically a commercial video projector, and the moving object, typically a planar object coated with photoresist. The scanning device allows the projector and the projected image to remain stationary

while the scanning device tracks the motion of the moving object until one frame is exposed. At the end of each frame the scanning device resets to the initial position while the image source changes the image to the next frame. The process repeats itself until a complete stripe of images is recorded. For imaging in the UV, the video projector lamp and the optics are modified in order to enhance the UV output. After one stripe of images is recorded further stripes are imaged using conventional two-dimensional scanning method. Either stepping or a continuous helical motion can be used to scan the second dimension of the object.

#### **Brief Description of the Drawings**

- Fig.1 is a schematic representation of the method, as applied to imaging onto a rotary cylinder.
- Fig. 2-a to 2-c show a sequence of tracking one frame and switching to the next frame.

#### **Description of the Preferred Embodiment**

Fig. 1 shows a generalized view of a commercial video projector 1. For clarity, the view is shown as a cut-away view showing some of the inside components of projector 1: a light source 2, typically a SHP type or UHP type arc lamp, a reflector 3, typically of the dichroic type, a rotating filter wheel 4, typically containing Red, Green and Blue filters, various mirrors 5 and a light valve 6. In the preferred embodiment the projector 1 uses a DMD (Digital Mirror Device, made by Texas Instruments of Plano, Texas) as a light valve. The two-dimensional image formed by the light valve 6 is projected by lens 7 onto

moving object 10, mounted on continuously rotating drum 11. The light valve 6 forms an image 12 on the object 10. In one application, object 10 is a light sensitive lithographic printing plate. The light from lens 7 is reflected off mirror 8 before reaching object 10. Mirror 8 is mounted on a fast galvanometer 9. The off-the-shelf video projector 1 can be modified to maximize the spectrum of the light in the region most effective for exposing the light sensitive coating. For example, if object 10 is a printing plate it is advantageous to maximize the light output of the projector in the UV range. This is done by replacing the filters in filter wheel 4 with filters that transmit UV light and block visible and infra-red light as well as changing the dichroic coating on reflector 3 to a coating which reflects UV and transmits other wavelength. If reflector 3 is effective, the filters on wheel 4 can be simply removed. Normally it would also be required to replace lens 7 with a lens optimized for UV and for a different magnification ratio. For lithographic plate applications, lens 7 should be replaced with a lens having a magnification of about 1:1.

The projector 1 is connected to a data source 13 in a conventional manner. The signal 14, used to synchronize the projected frames (typically 60 per second) to the data source, is also used to synchronize the galvanometer 9 via saw-tooth generator 15. All components of the system shown in Fig. 1 are well known, commercially available and no further details about them are required, as they can be purchased as complete functional assemblies.

The operation of the system is shown in Fig. 2-a to Fig. 2-c, which should be viewed in conjunction with Fig. 1. Mirror 8 is rotated at a velocity which makes any image point,

(by the way of example point "A" on light valve 6 imaged as point A') stay stationary relative to the moving object 10. Since object 10 is moving at a constant velocity the mirror 8 has to rotate in approximately linear fashion. At the end of the travel of mirror 8, shown in Fig. 2-b, mirror 8 has to return as fast as possible to the starting position, as shown in Fig. 2-c. At this moment the image on light valve 6 is changing and a new point "B" is imaged as point B', again stationary relative to moving object 10. The images containing points "A" and "B" can be imaged in a contiguous manner on object 10 or in an overlapping manner. The degree of overlap is determined by the ratio of the image size to the motion of object 10 during one image (frame) interval. By changing the speed of object 10 relative to the frame rate of projector 1 the amount of overlap is controlled. Obviously the data has to be changed in data source 13 to reflect the correct overlap.

It is also obvious to those versed in the art that saw-tooth waveform generator 15 is preferably a digital device including provisions for a look-up table. Such a table allows to modify the profile of the saw-tooth waveform to compensate for optical distortion introduced by the scanning process. Galvanometer drivers including look-up tables are well known in the art and commercially available.

It is also obvious that the motion of object 10 can be a linear motion instead of a rotary motion. A linear motion is used when scanning flat and rigid objects which cannot be wrapped around a drum. An example of using the invention with linear motions is the imaging of glass panels for electronic displays and the imaging of printed circuit boards.

When imaging a flat object moving back and forth the imaging process can be performed in both directions by reversing the direction at the galvanometer when motion direction is reversed.

By the way of example, a Computer-to-Plate machine is described. Projector 1 is Model 340B made by InFocus (Wilsonville, Oregon). All the filters are removed from color wheel 4 and the dichroic reflector is replaced with a UV-enhancing reflector optimized from 200nm to 450nm. The lens 7 is replaced with a fused-silica UV lens with a 1.04:1 magnification ratio of the double-gauss configuration. Mirror 8 and galvanometer 9 are made by Cambridge Instrument (Cambridge, Mass.), Model 6230. The frame rate used is 60Hz, with a saw-tooth rise time of 15mS and a retrace time of about 1.6mS. The saw-tooth is generated by a standard function generator. The moving object 10 is a lithographic printing plate of the projection type having a sensitivity of about  $5\text{mJ}/\text{cm}^2$  for UV light. The projected image is 600 x 800 pixels or about 6.34mm x 8.46mm. The speed of the drum 11 is adjusted to cover 6.34mm in 15mS, giving 0.42m/S. For a plate size of 50cm x 70cm and a drum circumference of 60cm, a complete image is written in about two minutes.

It is also clear that the relative motions of the projector 1 and object 10 can be reversed, and have projector 1 as well as galvanometer 9 and mirror 8 continuously moving while object 10 is stationary. Such a configuration is advantageous when object 10 is bulky, such as a container of liquid photopolymer.